Metrology for future energy transmission

3rd Newsletter

FutureEnergy project

This is the first newsletter of the EMPIR project ‘Metrology for future energy transmission (FutureEnergy)’. The three-year project started in June 2020, and it is building on the EMPIR projects ‘Metrology for the electric power industry (14IND08 ElPow), ‘Techniques for ultra-high voltage and very fast transients (15NRM02 UHV) and the EMRP project ‘HVDC future power grids (07ENG HVDC)’.

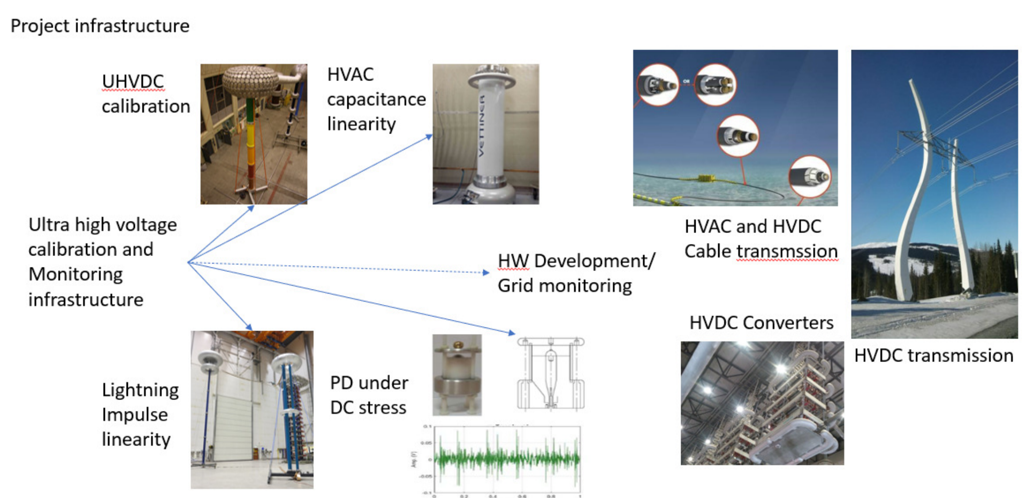
Driven by the need for increased efficiency, transmission grid voltages have been pushed to ultra-high voltages (UHV), beyond 1000 kV. This project will realise metrology solutions for grid component testing and condition monitoring required for successful implementation of future UHV transmission grids.

Society’s increasing demand for electrical energy, along with the increased integration of remote renewable generation has driven transmission levels to ever higher voltages in order to maintain (or improve) grid efficiency. Consequently, high voltage testing and monitoring beyond voltage levels covered by presently available metrology infrastructures are needed to secure availability and quality of supply.

Calibration services for UHVDC are not available above 1000 kV. There is a need to extend the calibration capabilities for voltage instrument transformers up to 1200 kV and for factory component testing capabilities up to 2000 kV.

The overall aim of the project is to provide traceability for metrology in testing and calibration of components for future electricity grids, and to provide improved means for HVDC grid condition monitoring. The specific objectives are:

- extend the traceable calibration of Ultra-High Voltage Direct Current (UHVDC) up to at least 1600 kV
- extend and research methods for lightning impulse voltage calibration for testing of UHV equipment
- develop a new method(s) for linearity determination of HV capacitors
- develop and demonstrate implementation of partial discharge (PD) measurements under d.c. stress
- facilitate the take up of the technology and measurement infrastructure developed in the project



Research highlights

UHVDC traceability

For the traceability to 1200 kV with the target measurement uncertainty of 40 µV/V, in total seven new 200 kV HV modules are being built. The target is to have at least two complete sets of HVDC dividers for traceability to 1200 kV in Europe, one complete at PTB and one at RISE. Field modelling to avoid corona discharge in the 1200 kV divider design has been completed by RISE with input from PTB, TUBITAK and VTT. Measurements have been performed by RISE to support the modelling. The results show which additional corona rings need to be added to joints between the HV modules.

All components have been ordered and the last components will be delivered in January 2022 for the final assembly of seven additional 1200 kV HVDC divider modules. The measurement campaign for traceability up to 1200 kV at RISE has been moved to March 2022.

For the traceability to 1600 kV with the target measurement uncertainty of 200 µV/V, a divider design based on work at PTB has been disseminated. PTB has finalised a prototype for 1600 kV and tested it in the open field at PTB. A complete low ripple 2000 kV UHVDC generator was designed and built by PTB for this purpose. Using the results from the first test has fed into the design and building of a fifth 400 kV module. Characterisation of the compete divider is ongoing for the final campaign with traceable measurement system to 1600 kV, aiming for extension to 2000 kV. Field modelling to avoid corona discharge for a 2000 kV divider has been completed by RISE with input from PTB, TUBITAK and VTT.

Lightning impulse linearity extension

Activities in preparation for drafting of the "Good Practice Guide" are ongoing. VTT has started modelling of the signal cable effects. First version of the simulation model based on telegraphers' equations embedded into circuit simulator is running.

In parallel to modeling, a literature study has been carried out by PTB and TUBITAK to investigate the influence of the attenuation in the coaxial cable between the high voltage hall and control room, as well as effect of measurement cable quality and length. Results from 14IND08 ElPow are being disseminated by RISE, and a bachelor thesis as well as a doctoral thesis at PTB shows several correlations which will feed into the "Good Practice Guide".

RISE has established collaborations in form of Letters of Agreement with 1) NIM, China, to support the work on front oscillations; 2) Haefely AG, Switzerland, to support the work on both front oscillations and cable effect; and 3) NMIA, Australia, to support the work on linearity extension methods. Further measurements and simulations and interaction with these collaborations have brought more insight into the problems addressed in the guide.

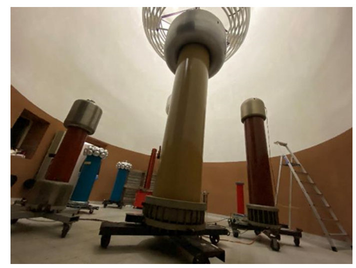
Updating and characterisation of 9 -12 measurement systems from eight partners as well as two collaborators, for a measurement campaign in October 2022 is in an intense phase.

Voltage linearity of UHVAC references

Information has been collected by TUBITAK on gas-capacitors accessible to project partners and their voltage dependencies based on which the best references will be selected as well as the measurement bridges.

Latzel's method has been repeated by LNE on a high-voltage capacitor to review the technique. The resulting measurements have been published. The new design of an 800 kV high-voltage capacitor has been finalised by VETTINER and a prototype was built. The collaborator NIM has proposed a "camera method" for non-linearity determination that has been evaluated by VETTINER.

VTT and VSL reviewed linearity extension techniques used in industry utilising electrical field probes. A new prototype field probe, to further develop the probe technique and the expected uncertainty, that has been designed by VSL is now being manufactured. Preliminary results were promising and will be improved by this probe. The work is ongoing and will serve as further input to VTT and TAU. VTT has performed direct measurements on two 180 kV capacitors to determine the non-linearity and further conducted measurements using a field probe up to 240 kV with good results.



PTB has measured the temperature dependence of their eight capacitors, which will be used in the development of the calibration method.

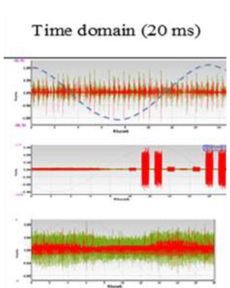
RISE established a collaboration in form of a Letter of Agreement with NIM, China, NMIA Australia and Haefely, to add to the work on new methods for voltage linearity determination. NIM China will send two dividers as well as Haefely for the big measurement campaign, adding to the understanding of capabilities of different divider designs.

HVDC grid condition monitoring

PD procedure for qualifying PD analysers used for d.c. measurement in the 1 – 30 MHz range

An attenuation study in HVAC and HVDC cable systems has been carried out. This study includes attenuation tests in AC cable samples (MV and HV) and theoretical determination for AC and DC cable systems. Attenuation is much lower in HV cable systems than in MV cables. Real data have been supplied from on-site tests.

Test cells of representative defects have been used for aging (floating electrode, cavity, corona, surface) in two different testing facilities. One site is focused on corona, on surface and on floating test cells and the other is focused on cavity defects. A comparison between real data and laboratory test cells has been performed with a small number of PD trains. The preliminary conclusion is positive: test cells represent real defects. Further comparisons are ongoing using a larger number of PD pulse trains. This led to a modification of the test-cells to prepare for ageing experiments.

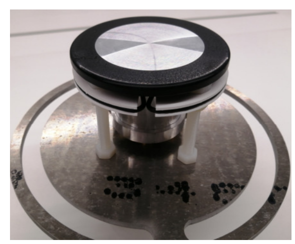


A set of 1000 PD pulse trains was supplied by a collaborator (DIAEL) to be used for an AI tool. First results from laboratory set-up using test cells are available. A neuronal network is being developed and DC PD pattern recognition has been developed by UPM.

An HVDC converter test cell has been developed for tests in a lab by UPM with support from FFII and discussed with RISE, TAU and TU Delft. A review of the bibliography about the state of the art of failures in DC and HVDC converters has been presented together with a test plan.

Real data of noises were obtained from real installations (wind plants, PLC from MV substations and DC plants). Several data have been prepared for a synthetic PD generator as noise data to be mixed with real PD defects. Data analysis continues to reproduce them by a synthetic way.
FFII has developed three software tools for characterisation of PD analysers for AC: a) PD sensitivity vs noise. b) PD pattern recognition. c) PD clustering. These tools allow the determination of the capabilities of PD analysers and are now extended to include DC PD patterns.

PD charge evaluation in HVDC GIS using magnetic sensors measuring in the 30 MHz – 300 MHz range
The magnetic antenna design for PD measurements in GIS has been improved extending the bandwidth above 300 MHz. A modification in the design has been introduced to minimise the effects of resonances. A mathematical model of the antenna frequency response has been developed that will be instrumental for the charge estimation of the partial discharges, which was published [4]. Analysis on the GIS PD signal attenuation is done in the working frequency range of the magnetic antenna.
The magnetic antenna frequency response has been extended above 300 MHz and reasons for resonances have been cleared. A mathematical model of the antenna response has been developed. A calibration testbench up to 1 GHz bandwidth has been built and tested. Preliminary work on charge estimation error calculation has been done, showing positive results. The work will be extended with theoretical developments and laboratory experiments to demonstrate the suitability of the proposed method based on the double time integral of the measured signal. The calibration of the charge estimation in GIS has been tested and verified in the test bench to prepare for a full-scale laboratory GIS for calibration [5]. An improved design of the magnetic antenna which shows better sensitivity is under research.



The collaboration with SuperGrid Institute has focused on testing the magnetic antenna under noisy conditions and testing artificial defects under SF6 and alternative gases.

The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

Contact and further information

The consortium consists of 7 National Metrology Institutes, 3 universities, and 2 companies and thus have measurement capabilities traceable to national standards, sites to host the measurements facilities and test their performance and companies to develop and exploit their technology.

Metrology for Future Energy Transmission

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To register as a project stakeholder, contact Alf-Peter Elg, RISE (alf.elg@ri.se).

Project partners:

	RISE	Research Institutes of Sweden	Sweden	NATIONAL METROLOGY INSTITUTES
	FFII	Fundación para el Fomento de la Innovación Industrial	Spain	NATIONAL METROLOGY INSTITUTES
	LNE	Laboratoire national de métrologie et d'essais	France	NATIONAL METROLOGY INSTITUTES
	PTB	Physikalisch-Technische Bundesanstalt	Germany	NATIONAL METROLOGY INSTITUTES
	TUBITAK	Turkiye Bilimsel ve Teknolojik Arastirma Kurumu	Turkey	NATIONAL METROLOGY INSTITUTES
	VSL	VSL B.V.	Netherlands	NATIONAL METROLOGY INSTITUTES
	VTT	Teknologian tutkimuskeskus VTT Oy	Finland	NATIONAL METROLOGY INSTITUTES
	TAU	Tampereen korkeakoulusäätiö sr	Finland	ACADEMIA
	TU Delft	Technische Universiteit Delft	Netherlands	ACADEMIA
	UPM	Universidad Poltécnica de Madrid	Spain	ACADEMIA
	Vettiner	Appareils Vettiner	France	INDUSTRY